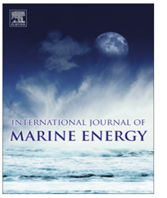
International Journal of Marine Energy 8 (2014) 70–83

Contents lists available at ScienceDirect

International Journal of Marine Energy

journal homepage: www.elsevier.com/locate/ijome



Verification within wave resource assessments. Part 2: Systematic trends in the fit of spectral values

E.C. Edwards [a,*], L.C. Cradden [a], D.M. Ingram [a], C. Kalogeri [b]

[a] Institute for Energy Systems, University of Edinburgh, Edinburgh EH9 3JL, UK
[b] Atmopsheric Modelling and Forecasting Group, National Kapodistrian University of Athens, Greece

ARTICLE INFO

Article history:
Received 12 September 2014
Accepted 2 October 2014
Available online 12 October 2014

Keywords:
Wave energy
Wave power
Resource assessment
Spectral analysis
Model validation
WAM
EMEC test site
Numerical model

ABSTRACT

Interest in wave energy as a viable renewable energy has increased greatly in the past couple of decades. To determine the potential that a certain location has to harvest wave energy, a resource assessment must be performed for that location. As wave energy converter technologies get closer to market, it is becoming necessary to undertake more detailed resource assessments to determine the optimal location for deployment as well as the design and operating sea states. This study shows the level of sophistication that must be included in the verification process within a wave resource assessment. We describe the methodology in two articles. Part 1 described a procedure for a complete statistical analysis of the fit of the model. This paper will demonstrate how investigating systematic trends in the fit of spectral values is essential for determining the precise problem areas of the model and is thus required as part of the verification processes. Lacking this detail could mean failing to notice potentially vital issues for energy extraction at the location of interest. The identification of specific problem areas will enable a well-informed consideration of the necessary next steps for improved prediction of energy extraction.

* Corresponding author.
E-mail address: emmae@mit.edu (E.C. Edwards).

http://dx.doi.org/10.1016/j.ijome.2014.10.001

1. Introduction

Part 1 revealed why it is important within a resource assessment to do a thorough statistical analysis of relevant parameters. Specifically, significant wave height and energy period calculations from the WAM3 CY331 model [1–3] were compared with corresponding measurements from a nearby Waverider buoy. Part 2 will demonstrate that it is also important to look beyond the parameters into the raw sea states by comparing spectra from the buoy and model. Comparing spectra will give a better understanding of the fit of the model at the location of interest. While comparing spectra is commonplace in many validation studies done by wave modellers, there are currently no resource assessments that quantitatively compare systematic problems in spectra for the model against *in situ* measurements. This analysis is essential for determining any subsequent steps that need to take place in a resource assessment to improve the reliability of predictions of resources.

In the introduction for Part 1, verifications or validation sections within global, national, and local resource assessments were reviewed. Within the studies mentioned, none of the global or national resource assessments revealed any spectral analysis. Within the local resource assessments, there were a few mentions of studying spectra, but no systematic analyses were done. Liberti et al. [4] examined the mean wave direction, and calculated circular statistics for bias and variance. van Nieuwkoope et al. [5] compared one-dimensional spectra for sites within the resource assessment, but this comparison was not done for the purpose of verification and there was no comparison to *in situ* measurements.

Wave models themselves are very well validated individually, and there have been an extensive number of very thorough studies describing validations of different wave models [6–11]. When doing a resource assessment, it is necessary to go into a similar amount of detail as these validations provide the necessary specific and accurate predictions for the energy sector. The WISE Group [12] produced a recent report on the current state of oceanographic wave modelling. Within this report, there is a section on the inevitable limitations of wave models and a description of different types of errors that can occur in models. These include errors due to resolution (geographic and spectral), diffusion, and dispersion, and many more types of errors. This paper indicates that although oceanographic wave models perform well overall, there are known areas of the models for which results need to be taken with caution. It is necessary to see if any of these problems occur at the location of interest for a resource assessment to determine the impact of the problems on the predictions, and finally to resolve further steps which need to be taken to improve the predictions.

Krogstad et al. [13] has a section on inter-comparisons of wave parameter measurements. Within this section, there is a description of a comparison of frequency spectra as well as a comparison of directional spectra. Demonstrating the high level of detail within this study, to compare the frequency spectra a plot was made of mean spectral ratio over fixed frequencies, and to compare directional spectra particular cases were presented by comparing the buoy results to the radar used. The aforementioned validation studies of wave models show varying amounts of detail, but most looked within the spectra at least to point out particular case studies.

Mackay et al. [14] concentrates on the Measure-Correlate-Predict (MCP) method of predicting an energy yield and shows how to find uncertainty bounds on the estimate. This is a very powerful method, but if the goal of a resource assessment is to understand the fit of the model to the location of interest with more detail, or to try to make the data more accurate, this method may not be appropriate.

These studies (Cavaleri, Krogstad, and Mackay) show the high level of detail within validations done by wave modellers. The purpose of Part 2 is to demonstrate the increasing importance of a high level of detail of verifications within resource assessments by comparing spectra. It is shown that the specific problems within the model used by this study at the location of interest occur within low-frequency waves coming from the West that are acting as intermediate-depth waves. These results give a further understanding of the fit of the model at the location off the Orkney Islands and insight into the next steps that need to be taken to improve the accuracy of the data for predicting wave power potential. Specifically, the fundamental next step in this analysis would be to use a coastal model, such as SWAN, to account for shallow water physics.

Section 2 will show methodology and results. First, background of the wave model used and the buoy data will be introduced (Section 2.1). Then, the specific records at which the model and buoy